The Lagrangian picture of heat transfer in convective turbulence

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Abstract

We present a fluid dynamics video which illustrates the Lagrangian aspects of local heat transfer in turbulent Rayleigh-Bénard convection. The data are obtained from a direct numerical simulation.

1 Video Description

If a fluid in an extended layer or a closed cell of height H is cooled from above and heated from below turbulent convection is initiated when the temperature drop between top and bottom plates is sufficiently large. The two videos, Video1 and Video2 (in higher resolution), show the motion of Lagrangian tracer particles in a Cartesian turbulent convection cell with periodic side walls and free-slip boundary conditions at the bottom and top plates ($z = 0$ and H). The direct numerical simulations solve the Boussinesq equations of Rayleigh-Bénard convection and are based on a pseudospectral method. The computational grid contains $N_x \times N_y \times N_z = 2048 \times 2048 \times 513$ points. A set of 1.2 million tracers is advected with the flow. The simulation parameters are Prandtl number $Pr = 0.7$, Rayleigh number $Ra = 1.2 \times 10^8$ and aspect ratio $\Gamma = L/H = 4$ with L being the sidelength in x and y directions [1, 2].

The subset of Lagrangian tracers, which is shown in the first part of the video, starts in a plane right above the thermal boundary layer. The tracer

particles are colored with respect to the total temperature T (red=hot and blue=cold) at their position. The diagonal cut through the evolving particle cloud illustrates the thermal plumes, which carry locally heat through the layer. A number of selected tracers are shown together with their particle track.

Heat is carried through the layer convectively when the product of vertical velocity fluctuation and temperature fluctuation is positive, $u_z\theta > 0$. This can be both, a hot rising plume and a cold downwelling plume. The final part of the animation colors the tracers with respect to their amplitude of $u_z\theta$. Levels of red stand for $u_z\theta > 0$ and white for $u_z\theta \leq 0$.

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References

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